|  |
| --- |
| THIS DOCUMENT HAS BEEN PREPARED FOR THE PURPOSES OF THE  **PROJECT RESOURCE CENTER**.   IT IS FOR GENERAL GUIDANCE PURPOSES ONLY AND SHOULD NOT BE USED AS A SUBSTITUTE  FOR SPECIFIC TECHNICAL, PROCUREMENT OR LEGAL ADVICE FOR A PROJECT |

# Terms of Reference

# Renewable Energy Mapping: SOLAR

## BACKGROUND

*<Rationale for the project, project history and list of relevant studies, key steps, need for consultancy services in the project, issues to be resolved, source of financing, country context, project context. >*

## OBJECTIVES

*<General Notes: Typical project objectives of an assignment may include the following: sector and strategy studies or assessments, project management and implementation supervision, collection and data analysis, etc.>*

The objective of the consulting assignment covered by this TOR is to support the sustainable expansion of electricity generation from solar power by providing the Government of [Country] and commercial developers with an improved understanding of the location and potential of solar resources at the country level.

## SCOPE of WORK

*<General Notes: This section of TOR details all the main activities to be conducted by the consultants and expected results of those activities. TOR should describe only the activities, not the approach or methodology by which the results are to be achieved>*

The assignment will cover up to the following three phases [*modify as appropriate*] of solar resource assessment:

Phase 1 - Scoping and preliminary modeling: Prepare an initial solar resource estimate for [Country] based on a model using existing satellite and other relevant data;

Phase 2 - Ground-based data collection: Prepare and carry out ground-based data collection using high quality solar measurement systems, with real-time data transmission and reporting, for the purpose of validating and improving the initial solar resource maps, and for generating reliable benchmarking data;

Phase 3 - Production of validated solar resource atlas: Prepare validated solar resource maps and a Solar Atlas report that describes the final outputs, methodology and process, and includes provision of the final GIS data.

Following Phase 1 the [Donor] may decide not to proceed with, or to delay, implementation of further phases. This may be because enhanced accuracy is not justified, because of changed circumstances, or due to a shortage of funds for completing ground-based data collection. The Consultant is therefore requested to submit a Technical and Financial Proposal that covers Phase 1 under a lump sum arrangement, with Phases 2-3 specified as optional extensions to the project. Should the [Donor] and the [Partner] wish to continue beyond Phase 1 a revised Scope of Work will be issued and the Vendor will be required to provide a revised Technical and Financial Proposal for Phases 2 and 3. This revised Scope of Work will describe the proposed scale and implementation arrangements for carrying out Phase 2, many of which cannot be determined at this stage in the project.

### PHASE 1: SCOPING AND PRELIMINARY MODELING

#### Project inception

Soon after contract signing, the Consultant shall take part in an Inception Mission to [City, Country] in coordination with the [Donor] project team. The objective of this meeting is to engage with the [Partner] and the [Donor] project team to outline the proposed methodology and timeline, and seek guidance and feedback. The Consultant shall use this opportunity to carry out a comprehensive assessment of any previous RE mapping work by meeting with relevant agencies and stakeholders, including the existence of any public and privately held solar data. In preparation for the Inception Mission the Consultant shall put together a slide pack outlining the status of solar development in [Country], the role that RE mapping can play, and a summary of the proposed work plan.

#### Solar resource modeling

The Consultant will be required to carry out an initial assessment of solar resources (including Direct Normal Irradiance, or DNI, Global Horizontal Irradiance, or GHI, and Diffuse Irradiance, or DIF) in [Country] based on the best available satellite remote sensing and meteorological data and produce a Solar Modeling Report. **Annex A** provides further details on the requirements for solar resource modeling and reporting.

The Consultant’s Technical Proposal shall clearly address all of the following points:

* Provide a general cloud and aerosol climatology of the area being analyzed indicating which aspects of the local climate and which areas are expected to be well represented by the satellite data or model, and which areas may have higher uncertainty.
* The modeling shall have a spatial resolution no coarser than 0.050 lat x 0.050 long. (~5-km) (Noting that satellite imagery allows resolutions as little as 1-km, which may be appropriate for complex terrain or shoreline regions). In the satellite methodology provided by the Consultant, each grid cell shall provide downloadable Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI), and Diffuse Irradiance (DIF) values at hourly or sub-hourly time steps.
* The data sources on which the modeling is based shall be specified in detail, including the resolution and the sampling technique used for each type of input data, such as Aerosol Optical Depth (AOD), atmospheric water vapor (WV), and trace gases in the atmosphere. For climatological data the time horizon and time step used for the data sampling shall also be specified.
* The model and/or methodology used in the calculations shall be described, and specified whether it is in the public domain, and whether it has been peer reviewed or not. If the model is proprietary and not in the public domain or published in peer reviewed journals, the Consultant shall describe the model(s) in detail, highlighting where their proprietary model(s) differs from public domain models. If the procedure is multi-staged or involves some sort of post-processing this shall be explained in detail.
* The extent to which the methodology has been tuned to match existing ground based solar measurement data shall be described. Studies that have been conducted to validate the methodology against independent data sources shall also be describe, and the results of these studies shall be reported. Furthermore, a method for further independent validation using data collected in Phase 2 of this study shall be described.

The Consultant will be required to submit an initial Model Validation Report #1 where ground-based data exists and is considered of sufficient quality and usefulness to justify this step; the Consultant is therefore requested to assess and comment on this as part of their Technical Proposal. If the Consultant is aware of additional data, or proposes further scoping work to source such data, then this shall also be included in the proposal. **Annex B** provides further details on the minimum requirements for Model Validation Reports.

If the Consultant proposes any field visits as part of undertaking Phase 1 (as part of, or separately to, the Inception Mission and the presentation of the outputs at an in-country workshop – see below), then the cost of doing so shall be included in the fixed-cost element of the technical proposal, and therefore fully justified by the proposed benefits.

#### Site identification

Following the solar resource modeling the Consultant shall prepare a Candidate Site Identification Report. This will include recommendations for the number of solar measurement devices and their respective Tiers, and a proposed longlist of possible site locations (see **Annex C** for Tier specifications). The Consultant’s recommendations shall take into account the needs for adequate model validation, availability of suitable locations and personnel to maintain the stations, and the likely available budget as communicated by the [Donor]. The Candidate Site Identification Report shall be presented to the [Donor] at least two weeks prior to the date of an in-country workshop to present the outputs from Phase 1 (see below).

The objective of ground-based data collection will be to provide high quality validation data and long-term historical solar reference data for the country solar atlas, rather than to obtain data for specific grid-tied solar power plants. The sites shall thus be selected so as to represent dispersed high-solar zones with potentially commercially exploitable solar resources, as well as representing different local climate and/or topographical conditions, where the approach used for the Phase 1 solar map may exhibit poor performance.

The [Donor] is keen to maximize potential synergies and cost savings by carrying out wind and solar data collection on/near the same sites when technically feasible. The site selection criteria shall accommodate this where possible.

The [Donor]’s in-house GIS team will work concurrently to the Consultant to source or commissioning all necessary GIS data layers (aside from the solar resource mapping layers[[1]](#footnote-1), and assuming data availability within reasonable budget), making these available to the Consultant within two months of contract signing. This work will therefore begin as soon as possible (and most likely prior to the issuing of the Consultant’s contract), and will include the following layers where data are available: transmission grid, roads, cities, administrative borders and geographical names, protected environmental/historical/archeological/safety/military zones, shipping lanes, takeoff and landing corridors, and microwave transmission paths.

#### Phase 1 workshop

Once draft Phase 1 outputs have been submitted and approved by the [Donor], the Consultant shall participate in a three day workshop held in [City] to present the results to the [Partner], discuss next steps, and provide a package of training. As far as possible, the workshop will be timed to coincide with scoping studies and the presentation of the outputs from parallel work on other RE resources. The Consultant’s Technical Proposal shall propose a format for this event, including a description of the in-country training for end users (government and regulatory officials, representatives from utility operating companies, potential wind developers). The Consultant should assume in their proposal that the [Partner] and/or the [Donor] will host the event, including provision of meeting room space, logistics, translation and sending of invitations. The Consultant’s proposal shall include the cost of their participation in this workshop including delivery of the training components.

#### Revised Scope of Work

Towards the ends of Phase 1 the [Donor] in consultation with the [Partner], will determine whether to proceed with Phases 2 and 3, taking into account the available budget. If the decision is taken to proceed then the [Donor] will prepare a revised Scope of Work for Phases 2 and 3 drawing on this TOR and including further details on implementation arrangements, including involvement of [Partner] counterpart agencies. The Consultant will then be required to submit a revised Technical and Financial Proposal for Phases 2 and 3, drawing on the fixed cost elements contained in their original Financial Proposal in response to this RFP and also the day rates agreed under the framework contract with the [Donor]. If this is accepted by the [Donor] then an amendment to the original contract will be signed to allow the work to proceed.

### PHASE 2: GROUND-BASED DATA COLLECTION

#### Site selection

Following a decision to proceed with Phase 2, the [Donor] will facilitate discussions between the Consultant and the [Partner] to develop a shortlist of sites for further consideration, drawing on the longlist proposed in the Candidate Site Identification Report. This may happen as part of, or immediately following, the Phase 1 workshop, as a separate country mission, or via remote communication. Shortlisted sites will then be visited by a small team, including relevant experts from the Consultant’s team and potentially [Donor] and [Partner] representatives. The objective of these visits will be to assess any localized site constraints and potential adverse impacts, and carry out appropriate consultations, before recommending a final set of measurement sites.

Following the field visits the Consultant will need to prepare and submit a Phase 2 Implementation Plan containing final site selection details, arrangements for permitting, commissioning and maintenance, and proposed capacity building measures.

#### Solar measurement program

Upon agreement of the Phase 2 Implementation Plan by the [Partner], and subsequent approval by the [Donor], the Consultant shall be responsible for obtaining high quality solar data from the agree list of sites (which at the minimum is expected to include at least one Tier 1 station, at least [number] Tier 2 stations, and at least [number] Tier 3 stations) over a 12-month period, with the option to extend this to 24 months. This will include purchase, installation, operation and maintenance of the required equipment, and associated requirements in terms of obtaining permits and local approvals, third-party liability insurance, security arrangements and all other factors relating to commissioning, operation and maintenance. For the purposes of their Financial Proposal, the Consultant should assume at least [number] Tier 1 station, [number] Tier 2 stations, and [number] Tier 3 stations, with costs sufficiently itemized to allow for these numbers to be increased or decreased according to the Consultant’s eventual recommendations, the needs of the [Partner], and the available budget.

Equipment ownership details will be finalized during Phase 1 and incorporated into the revised Scope of Work, but may include Consultant ownership (for the life of the measurement program), joint Consultant-[Partner] ownership, or ownership transfer from the Consultant to the [Partner] upon commissioning. Note that the precise details with regard to legal ownership will not change the requirement for the Consultant to be responsible for all matters relating to commissioning, operation and maintenance of the equipment for the 12/24-month measurement period.

As it is preferable (but dependent on site conditions) for the measurement equipment to remain in place for longer than two years in order to provide a continuous reference data series to be used for recalibrating future local solar measurements to a long-term normal solar year, the presumption is that regardless of the ownership option agreed during the 12/24-month measurement campaign, sole ownership of the equipment will be passed to the [Partner] once the contracted period ends. This would be structured to begin on the day immediately after 12/24 months of measurement data are obtained for all sites.

The Consultant shall provide a description of the capacity building they would offer to enable the [Partner], or the [Partner]’s nominated agency/organization(s), to take over operation and maintenance of the equipment at the end of the contracted measurement period. As a minimum, the Consultant is expected to train nominated personnel (to be specified in the revised Scope of Work for Phases 2-3) to carry out continuing meteorology measurements through training in mast maintenance, data quality control and both remote and on-site (emergency) data collection. The Consultant shall also invite nominated personnel to attend equipment commissioning and recalibration, and will supply checklists for both maintenance and data collection. The Consultant is encouraged to specify any existing relationships they have with local agencies or suggestions in this regard. As part of the revised Scope of Work issued prior to commissioning of Phases 2 and 3, details of any local agency or partner that the Consultant will be required to work with, and the nature of the proposed collaboration, including responsibilities in terms of permitting and payment of import duties, will be provided.

The safe installation and operation of any solar measurement equipment, including site maintenance and security, will be the responsibility of the Consultant or their nominated sub-contractor and/or local partner agency for the duration of the project. With regard to site security, the Consultant is required to ensure the following:

* Any security arrangements put in place by the Consultant shall be proportional and appropriate.
* The Consultant shall be guided by good international practice and applicable law in relation to the hiring of security personnel (e.g. due diligence on the past conduct of the security personnel), rules of conduct, training, and equipment provision.
* Appropriate oversight and control measures of security personnel shall be in place.
* Information will be made available at each site on appropriate contact persons in case of queries or concerns.
* The procurement of arms and ammunition, nor for the training of security workers in the use of arms.

The Consultant will be responsible for all third party liabilities associated with such equipment over the course of the measurement campaign. It is suggested that the Consultant includes estimated insurance costs in their Financial Proposal on the understanding that detailed quotations will be obtained once the revised Scope of Work is issued and included in the Consultant’s revised Financial Proposal.

The Consultant’s Technical Proposal shall include a description of the standards and methodology to be deployed as part of the data collection campaign, in compliance with the technical requirements specified in **Annex C**, and including the following considerations:

* The Consultant shall provide and install all measurement equipment at each site, and will be responsible for sourcing, transporting, installing, maintaining, insuring, and safe-guarding the equipment, and all associated third party liabilities.
* The Consultant is required to obtain all necessary permissions from public authorities, including, but not limited to, land use rights, land access permits, permits for installation of measurement equipment, notification or permitting from national, regional and local planning authorities, environmental and social impact approvals, civil aviation permitting, telecommunications licensing including satellite or cellular communications (if needed), customs clearance, exemption from duties and taxes where relevant.
* The [Partner] will, to the extent possible, assist the Consultant by facilitating contacts with public authorities.
* The Consultant shall post all measurement data to a secure, web-based data repository to be established by the [Donor], with the presumption that all data will be publicly available (either immediately or after verification, as decided by the [Donor] in consultation with the [Partner]); the repository shall hold the measurement data, metadata and sensor documentation including maintenance logs for each site, as well as the GIS layers generated over the course of the project. The measurement data, metadata and sensor documentation are the property of the [Donor].
* Based on the requirements in **Annex C**, the Consultant and/or their partners/subcontractors shall inspect the measurement equipment at the required frequency, perform the needed maintenance to ensure the safety and functionality of the sensors and mounting hardware, and maintain a spare parts inventory and propose a service policy which will meet the minimum measurements specified.
* The Consultant is solely responsible for any deficiency in the design, installation and maintenance of each solar monitoring station. The failure of the [Donor] to object to or fail to monitor any aspect of the solar measurement program shall not be construed as a waiver by the [Donor] or in any way relieve the Consultant of its obligations under this assignment.
* If the data recovery rate of 95% as specified in **Annex C** is not fulfilled, the measurements shall continue until the [Donor] finds the data coverage satisfactory using the criteria outlined; the expenses in relation to continuation will be financed by the Consultant, and will extend the duration of the measurement period beyond the agreed period.

The Consultant shall prepare a Site Installation Report immediately following commissioning of each site to provide a permanent record of the site characteristics, measurement equipment, and other variables as outlined in **Annex C**. The Site Installation Report shall include photographic images for each site at the point of commissioning, including panoramic views of the area, the installation process, and the equipment in-situ. These images shall be separately submitted to the [Donor] along with precise GPS coordinates for each site, a full equipment inventory, and details of the commissioning date and maintenance schedule. This information will be added to a database on global wind measurement masts, and the images may be used in [Donor] communications. All images shall conform to the standards specified in **Annex E**.

The Consultant shall also prepare a Site Resource Report at the end of 12 (and 24) months of measurements, within six weeks of the end of this/each period. The purpose of the Site Resource Report is to document site measurement operations for quality assessment purposes and to provide measured datasets which can be used to compare with the results of the solar modeling. Minimum requirements for Site Resource Reports can be found in **Annex D**.

The Consultant’s Financial Proposal shall specify a fixed cost for delivery of the measurement campaign as specified above, detailing the additional costs that would apply if: i) one or more additional sites were included in the final scope; ii) the measurement campaign was extended to 24 months, including production of an additional Site Resource Report. The Consultant should assume use of their preferred suppliers in preparing their Financial Proposal; any deviation from this in the revised Scope of Work (for example, as a result of [Partner] demands or the need to build capacity) can be accounted for in a revised Financial Proposal, if required. The Consultant should assume a high degree of geographic diversity and reasonable road access for the purposes of estimating costs.

### PHASE 3: PRODUCTION OF VALIDATED SOLAR RESOURCE ATLAS

The Consultant shall deliver a Model Validation Report #2 once the measurement campaign is completed incorporating the measured solar data from these sites, and any solar measurement data provided by the [Partner] (including any data not available during Phase 1). The Consultant should explain if they propose to modify or adjust their solar resource model at this stage, and if so, how they propose to use the ground-based data to update the modeling results. If the Consultant does produce a revised solar model, the results shall be documented in a Solar Modeling Report #2, with the Model Validation Report #2 produced thereafter. The Consultant’s Technical Proposal shall clearly outline the methodology proposed and include all associated costs in the fixed cost elements of their Financial Proposal.

The Consultant shall then produce a final Solar Atlas for delivery to the [Donor] and the [Partner] in the format of a stand-alone report, slide pack, and relevant GIS layers. The Solar Atlas report shall provide a summary of the methodology and process, references to the previous report and data outputs, and high quality representations of the final mapping outputs, including validated solar resource maps as relevant. It shall be delivered in electronic format suitable for print and web publication.

It is anticipated that a second workshop would be organized at the end of Phase 3 to present the outputs to the [Partner] and in-country stakeholders, at which time the Consultant will be expected to participate alongside any local partners involved in carrying out the work.

## Deliverables / specific outputs expected from Consultant

*<General Note: The assignment reporting requirements should be clearly specified and balanced. Consultants should not be forced to spend an excessive amount of time preparing minor reports. TOR should also indicate the formant, frequency, and content of reports as well as the number of copies, the language, and prospective recipients (without disclosing the names)>*

### PHASE 1 DELIVERABLES

During Phase 1 the Consultant shall deliver the following:

1. Solar Modeling Report #1
2. Model Validation Report #1 (if ground-based solar data are available).
3. Numerical solar resource database as specified in Annex A and relevant solar GIS layers on a suitable storage medium. The database shall be compatible with the IRENA Global Atlas data catalogue and the GIS layers shall be compatible with OGC standard web mapping services (see Annex E for more details).
4. Candidate Site Identification Report outlining a longlist of proposed sites for a ground-based measurement campaign.
5. Inputs to the Phase 1 workshop to be held in [City] including training and capacity building.
6. Preparation of revised Technical and Financial Proposals for Phases 2-3 if the [Donor] (in consultation with the [Partner]) decides to proceed beyond Phase 1.

### PHASE 2 DELIVERABLES

During Phase 2 the Consultant shall deliver the following:

1. Advice on site selection, including participation in field visits to shortlisted sites.
2. Phase 2 Implementation Plan including details of the final selected sites.
3. Implementation of a ground-based measurement campaign the agreed-upon number of sites according to the Tiers and standards specified in these TOR, including provision of measurement data in the specified formats.
4. For each installed site, a Site Installation Report including photographic images as specified in Annexes C and E.
5. For each installed site, a brief Site Resource Report #1 on completion of 12 months solar data collection (and long-term reference data).
6. For each installed site, a final Site Resource Report #2 upon completion of an additional 12 months solar data collection (and long-term reference data), if the measurement campaign is extended.

### PHASE 3 DELIVERABLES

During Phase 3 the Consultant shall deliver the following:

1. Model Validation Report #2 OR production of a Solar Modeling Report #2 followed by a Model Validation Report #2.
2. Final Solar Atlas to be delivered as a stand-alone report (containing map visualizations) suitable for publication accompanied by a slide pack and final GIS layers in the specified formats.
3. Input to a Phase 3 workshop in [City] to present the results to the [Partner] in conjunction with local partners including training and capacity building.

### TIMELINE

Anticipated milestones are as follows:

|  |  |
| --- | --- |
| **MILESTONE** | **DATE** |
| 1. RFP issued | Month 0 |
| 1. RFP deadline | Month 1 |
| 1. Contract awarded | Month 1-2 |
| 1. Inception mission | Month 2 |
| 1. Delivery of preliminary mapping outputs | Month 4-5 |
| 1. Phase 1 workshop | Month 5-6 |
| 1. Revised Scope of Work agreed | Month 6-7 |
| 1. Phase 2 begins | Month 8+ |
| 1. Phase 3 begins | Month 20+ OR Month 28+ |

If the Consultant feels that the timeline proposed above is unrealistic, or that meeting it will substantially increase costs, then they should propose an alternative timeline in their Technical Proposal and/or note any constraints on their side.

## Specific input provided to the consultant

[Number] topographical maps of the areas containing the geographical reference points of the [number] proposed sites 1:50,000 or best available scale.

Relevant background geospatial (GIS) data to help inform the preparation of the Small Hydro Atlas and subsequent discussions, dependent on availability. The [Donor] will take account of the Consultant’s stated needs in determining what GIS layers to prepare, notwithstanding issues around data availability and cost.

The [Donor] and the [Partner] will facilitate links to local agencies or other organizations for obtaining historical hydrological data and documentation for any previous ground-based measurements, to be provided at no cost where possible.

Central data repository and geo-portal for the long-term storage and access of all data and GIS layers generated under this project.

Further details on the implementation of Phases 2 and 3, as contained in a revised Scope of Work to be prepared towards the end of, or following, Phase 1.

## Specific input provided to the consultant

The evaluation of proposals will be conducted according to a [number]: [number] split between the Technical and Financial Proposals.

Technical Proposals, which should be no longer than [number] sides, will be evaluated against three criteria, as follows:

i) The methodology, broken down into the three Phases that come under this RFP, and assessed according to methodological rigor, the appropriate sequencing of activities, the comprehensiveness of the approach with regard to quality standards and safeguards, and the value added in terms of innovative approaches and/or improvements to the TOR.

ii) The Consultant’s proposed team, assessed according to their combined and individual experience (both globally and in-country), appropriate balance between roles and use of senior/junior staff, and clear line of sight with regard to responsibilities. Consultants are strongly encouraged to deploy qualified local partners having expertise in the required field, where feasible. Local partners will prove to be useful in arranging access to sites, acquiring permits from concerned authorities, and contributing to successful completion of the assignment, especially during Phase 2.

iii) Other factors, including appropriateness of the capacity building plan and training activities, proposed plan for engagement with [Partner] and external stakeholders, involvement of local partners and service providers, and the stated flexibility of the Vendor in being willing and able to respond to minor changes during implementation.

The Consultant shall provide a Financial Proposal that conforms to the terms (and specified unit rates) of the existing Indefinite Delivery Agreement (Framework Contract), and includes:

• A fixed cost offer for each of the three Phases as specified in the Scope of Work, broken down by deliverables.

• A fixed cost offer for the project extensions and optional components specified in the Scope of Work, including:

o each additional data collection site over and above the number of sites specified above, including any quantity discounts;

o the cost of extending the measurement campaign to 24 months, including the additional Site Resource Report.

• A fixed cost offer for any deliverables that are not listed in these TOR but are being proposed by the Vendor in their Technical Proposal as optional additions to the Scope of Work. Any optional/additional deliverables shall be offered on a fixed cost basis and would be agreed upon in the contract negotiation phase or during project implementation.

• A breakdown of personnel costs and estimated reimbursable expenses.

• A proposed payment schedule against major milestones/deliverables, following an initial payment of [number]% of the total for Phase 1 on contract signing, and [number]% of Phases 2-3 on contract extension.

The Consultant is required to use the special template provided for their Financial Proposal and disregard the standard ‘Financial Proposal Template’. The Consultant shall provide their offer in the currency specified in their Delivery Agreement, and alter the Financial Proposal accordingly.

All travel charged by the Consultant shall be for economy class flights via the most direct route; [Donor] negotiated rates for hotel accommodation should be used where possible. All travel and subsistence shall be treated as a reimbursable expense but the Consultant shall provide estimated costs in their Financial Proposal and include this in their fixed price offer.

The [Donor], at its sole discretion, may decide not to continue the work beyond Phase 1, depending on the conclusions drawn from the Phase 1 outputs and the wishes of the [Partner].

## Annex A: Minimum requirements for solar resource modeling and reporting

The Consultant shall provide the following gridded (raster) products compatible with Geographic Information Systems (GIS):

* GIS data layers of all three components of the solar resource: GHI, DNI, and DIF in units of KW-hr/m2/day.
* Gridded maps of the solar resource falling on a flat plate collector oriented toward the south (in northern latitudes) or the north (for southern latitudes) tilted from the horizontal at an angle equivalent to the local latitude, or another optimal angle proposed by the Consultant, and labeled as “Global Tilt Irradiance” (or “GTI”) in units of KW-hr/m2/day.
* Color-coded maps of long-term monthly and annual values of GHI, DNI, DIF, and GTI in units of KW-hr/m2/day.

Care shall be taken to ensure that the data are properly documented and stored in a standard geo-referenced format, so that subsequent analysis can be undertaken.

The data products shall meet the following specifications:

* Solar resource data layers shall be shown as average daily totals of irradiation per month and per year in kWh/m2, with the accuracy of three decimal points;
* Grid sizes shall be no larger than 0.050 lat. x 0.050 long. (~5-km), and shall be established on a latitude-longitude projection;
* When initial maps are produced, no smoothing shall be done. Maps shall show the gridded values. The Consultant can create additional smoothed maps, but shall specify any additional costs in producing these maps;
* Data shall be color coded so that higher resources are yellow and red, lower resources are blue. Increments of 0.5 kWh/m2-day shall be adopted for the color coding and mapping scheme;
* The maps shall include the point location of any existing ground measurement stations that were made available to the mapping effort. Gridded data layers of these point locations shall be created;
* If the model used to create the solar information uses terrain elevation (for example, to account for decreasing AOD with height or for local shadowing on the grid cell due to higher surrounding terrain) the Consultant shall provide a digital terrain elevation map based on the DEM used in the modeling process, unless the Consultant chooses to use the DEM provided by the [Donor], as indicated in Section 4.

As part of the Solar Modeling Report, the Consultant shall include monthly and annual maps of kWh/kWpeak, which allow for calculation of monthly and annual energy production potential (or capacity factor) for a typical high efficiency crystalline-silicon solar panel installed at optimal tilt. Assumptions on panel configurations and efficiencies at Standard Test Conditions to produce these maps shall be specified by the Consultant.

The Solar Modeling Report shall also include tables or maps indicating the inter-annual variability of the solar resource for the period in which the input data are available.

## Annex B: Minimum requirements for Model Validation Reports

As a minimum, the solar model validation report(s) shall contain the following:

1. Geographical names of all the solar monitoring stations used for this report with footnotes indicating the source institution for the data;
2. Accurate (+ 1 arc-sec) geographic coordinates (latitude and longitude) for the location of the solar sensors, as well as the geographic coordinates for the corresponding grid center points;
3. The measurement period used and the data recovery rates of the ground stations (please comment on seasonal bias in the sample, if any);
4. Results of data quality assessment procedures applied to the ground data;
5. A detailed description of the validation methodology, including types of field calibration instruments used, and the traceability of these validation methods back to the World Radiometric Reference;
6. A summary and recommendation for ongoing and future operations of the data network.

A table shall be included with the Consultant’s interpretation of the data for the entire sample of modeled and measured data used in the validation study, to include: Mean Bias Deviation; Mean Absolute Deviation; and RMS (root mean squared) Deviation in absolute values and in %. The number of valid hourly or sub-hourly data pairs of measured and modeled values shall be stated for each validation point.

The Consultant shall analyze and explain deviations between model results and measurements, and in particular indicate geographic areas or aspects, which require special attention because of systematic biases.

## Annex C: Minimum requirements for solar measurement procedures

Under Phase 2 the Consultant shall design and install stations throughout the country giving consideration to three different tiers of ground measurement stations for installation as specified below. The Consultant may propose an alternative set of standards and/or methodology in place of these requirements, but they should provide an equivalent or better performance and reliability. Should site conditions warrant this, the Consultant may also propose additional (or less) instrumentation.

### Tier 1

A research-quality station that utilizes thermopile radiometers to measure all three components (GHI, DNI, and DIF). The sensors chosen for the GHI and DIF measurements must meet ISO Secondary Standards (or alternatively WMO High Quality Characteristics); the sensors chosen for the DNI measurements must meet at least ISO First Class (or alternatively WMO Good Quality) standards. Optional equipment at a Tier 1 station, suitable especially for arid, dusty environments, could also include pyrgeometers (for infrared flux measurements), photometers (for measuring the aerosol loading of the atmosphere), and a spectroradiometer to measure the solar irradiance at different spectral wavelengths. Optional equipment shall be costed separately in the Consultant’s cost proposal. At a Tier 1 station, an automatic tracker is used for the DNI measurements, and shading balls on trackers are used for the diffuse measurements. Such a station provides the highest accuracy measurements, and ideally at least one Tier 1 station will be installed in a given country. Temperature, humidity, barometric pressure, and wind speed and direction data at 10-m above the ground must also be collected. Tier 1 stations must be installed at a location where trained personnel are readily available to operate the station properly. These stations shall be designed to achieve measurement uncertainties of 2% to 3% for one-minute values, and <2% for daily GHI and <1% for daily DNI values.

### Tier 2

Mid-Range Station, which makes use of a Rotating Shadobank and Radiometer (RSR) that is capable of providing all three components (GHI, DNI and Diffuse). Temperature, humidity, barometric pressure, and wind speed measurements at a height of 3 – 5m above ground level (agl) shall also be collected at Tier 2 stations. As an option, an ISO Secondary Standard pyranometer shall also be included in Tier 2 stations to allow for quality control and calibration of the RSR equipment. A Tier 2 station can provide measurement uncertainty of <5% for daily values.

### Tier 3

Simple Station, consisting of a GHI and Plane of Array (POA) photodiode sensor, and can achieve GHI measurement uncertainties of ~5% for daily values. Tier 3 stations are not expected to be deployed in this project except in cases where Tier 3 equipment can be used as an additional sensor associated with a wind monitoring station, or where DNI levels are expected to be so low as to not be suitable for commercial deployment of concentrating technologies, thereby negating the need to obtain DNI measurements.

#### Specific requirements are as follows:

* The solar monitoring equipment, the station containing other weather sensors, as well as any on-site data logger equipment is easily accessible for cleaning, level checks, and maintenance.
* The equipment must be adequately protected from corrosion and dust to operate safely in the environment in which it is installed.
* The equipment needs to be protected from lightning strikes and shielded from radio frequency interference. In general, a single point ground using a copper rod deep in the ground shall be installed. Twisted pair cables shall be used for low voltage measurements. The low voltage sensor cables shall be physically isolated from power cables (not run in parallel or in the same conduit). Masts and tripods for mounting meteorological equipment shall be well grounded to assure a path for lightning strikes. As an option, Metal Oxide varistors, or gas tubes, can be used to protect signal cables from electrical surges.
* The solar monitoring equipment must be sited to minimize conditions that might cause shading of the equipment, such as nearby trees, buildings, or other tall objects. The weather sensors shall be installed at a location that does not shade the solar sensors.
* The equipment shall include factory calibrations.
* Temperature, humidity, barometric pressure and wind speed and direction must be measured using calibrated instruments.
* The station, including the data logging equipment, must be powered adequately for proper year-round operation. There must be adequate local data storage capacity for at least one month. Should the Consultant wish to deviate from our recommendation, we require a detailed justification for considering the proposed change.
* Data must be collected at minimum 1-s sampling frequency, averaged over 1-minute time intervals. If the equipment allows, sample rates even faster than 1-s shall be captured for possible future analysis.
* Data recovery rates from each of the solar monitoring sensors must be above 95% during any 12-month period. Data losses must be seasonally dispersed. Lost data intervals above 12 consecutive days are not acceptable for any instrument, and will require the measurement campaign to be prolonged.
* The Consultant shall maintain the solar and meteorological equipment throughout the measurement campaign. Arrangements shall be made to inspect Tier 1 (and Tier 2 thermopile) solar monitoring equipment daily, including cleaning the sensors and checking the sensor levels. RSR equipment shall be cleaned and inspected weekly. Timer settings on the data loggers shall always be set to local standard time, and shall be verified during inspections.
* Data download from the solar and meteorological equipment must be done at least twice weekly and checked to ensure against data loss, corrupted data, calibration drift, and instrument failure.
* Data must be transmitted electronically through a cell phone connection, (or satellite connection if cell phone coverage is inadequate) from each sensor. There must be a manual backup data collection procedure for each station, which can be activated within 24 hours in order to minimize data loss.
* All collected data and quality-assessed data shall be uploaded to a data repository provided by the [Donor]. Data transmission (from each measurement site and to the data repository) is the responsibility of the Consultant and all costs shall be included in their Financial Proposal.
* During the measurement campaign a historical log report shall be maintained documenting all maintenance undertaken, date and reason for replacement of instruments, etc. The log report shall be available online through the web site mentioned above.
* The Consultant shall notify the [Donor] by email before and after all maintenance visits. The Consultant shall forward the updated historical log report within 7 days of the visit and upload the report to the [Donor] web site.
* A **Site Installation Report** shall be prepared for each site, which shall include, but not be limited to:
  + Exact location details, including coordinate system and Datum info. There shall be GPS loggings at each station at the location of the solar sensors to within an accuracy of 1-meter. All references shall be according to geographical North instead of Magnetic North.
  + Configuration drawing of the station layout, including location of each sensor.
  + Photos and a list of instruments including brand, model and serial numbers
  + Pictures of mounting details of each instrument
  + Picture of data logger and logger cabinet
  + Documentation photos of the station installation, including the installation of the meteorological sensors
  + Directional pictures of the area looking out from the station position in 30° angles, starting from straight North (0°) and moving clockwise, to be taken after station installation
  + Picture of the fully installed station including exact coordinates from where picture is taken
  + Calibration and recalibration certificates for each instrument
  + All data logger settings and a copy of the logger’s software program.
* This information shall be made publically available by the [Donor] and linked to the data repository mentioned above.
* The Consultant shall propose a suitable inventory of spare parts, which shall be available e.g. for instrument replacement at short notice.
* The Consultant shall quote a separate price for replacement and recalibration of one or more solar monitoring sensors at each station.

## Annex D: Minimum requirements for Site Resource Reports

Consultants shall carry out the following for the preparation of Site Resource Reports:

1. Review and quality checking of measured solar data from the site using standard quality assessment software such as NREL’s SERI QC (following the procedures described on pp. 287-289 in the reference called out in footnotes 11, Annex C);
2. Report on the calibration procedures and results of the pyranometers and pyrheliometers, including pre and post calibrations for the 24-month study, as well as field calibrations using a reference pyranometer. The report shall include how the calibration procedures relate to the World Radiometric Reference that is established in Davos, Switzerland every five years;
3. Analysis of how well the on-site measurements compare with long-term data such as derived from the satellite-derived resource modeling conducted in Phase 1 for the grid cell that most closely represents the ground station. Comparisons in this case can include correlations, mean bias differences, and root mean square differences, as well as Kolmogorov-Smirnoff statistics;
4. Estimate of the uncertainty in the prediction of the long-term GHI and DNI at each site based on i) through iii);
5. Analysis of seasonal and diurnal characteristics of the measured GHI and DNI;
6. Monthly summaries of any other meteorological parameters captured at the site;
7. Statistical analysis of the frequency of occurrence of GHI and DNI 1-min “ramps” at each site.

## Annex E: General requirements for data, maps and images

### Non-geographic data

All non-geographic data shall be made available in the following data formats for upload to a data repository, most likely via an Application Programming Interface (API) provided by the [Donor]:

* .csv (csv output from an excel file)
* .xls (Excel 97 and later)
* .xlsx (2007 and later)
* .tsv

### Geographic data

All geographic data shall be delivered as shapefiles, file geodatabases, or other accepted OGC standard geographic formats. Preferred formats are shapefiles for vector data, and GeoTiff for raster data. See table below for some further details:

|  |  |  |
| --- | --- | --- |
| **Dataset** | **Format** | **Spatial Reference** |
| Vector | Shapefile | Geographic Coordinate System: GCS\_WGS\_1984  Datum: D\_WGS\_1984  Prime Meridian: Greenwich  Angular Unit: Degree |
| Raster | Tiff, Grids, or Imagine | Geographic Coordinate System: GCS\_WGS\_1984  Datum: D\_WGS\_1984  Prime Meridian: Greenwich  Angular Unit: Degree |
| Tabular | .csv, .dbf or .xls | XY coordinates must be in Decimal Degrees |

All files pertaining to the map creation, such as .mxd or .ai files shall be included in the delivery of the GIS data. In addition to the format requirements, all geographic data provided must be accompanied by detailed metadata as outlined in Annex A. The [Donor] metadata standards are based on ISO [code] (Geographic Metadata Standards).

### Images

Mapping and other images shall be supplied with a 300 dpi density and lossless compression (PNG), suitable for professional printing. Mapping images will be reviewed by the [Donor]’s GIS team before going to publication to ensure cartographic quality and content. Images may be used by the World [Donor] for communications purposes.

All photos shall be delivered in their original high-resolution format (raw or .jpg), preferably exif-tagged with GPS and timestamp.

1. Which include input layers such as elevation, steep inclines, and land/water masks. [↑](#footnote-ref-1)